Effects of Seeding Rates and Competition on Sagebrush Establishment on Mined Lands

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Abstract

Shrub establishment on reclaimed coal mines of the Powder River Basin in Wyoming is a vital component of reclamation. Efforts to revegetate using xerophytic shrubs have been unsuccessful due to competition for moisture, poor seedling vigor, and altered edaphic conditions. As a result, methods to re-establish Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) are needed to meet shrub density standards. This study examines effects of grass competition and sagebrush seeding rate upon establishment of big sagebrush seedlings at the Belle Ayr Coal Mine near Gillette Wyoming. Experimental plots seeded with three sagebrush rates (1, 2, and 4 PLS kg/ha) and seven rates of a grass mixture (0, 2, 4, 6, 8, 10, and 14 PLS kg/ha) were used to assess effects of sagebrush seeding rate and grass competition on seedling density and survival. Data from four sagebrush seedling counts (June 30, August 3, August 31, and October 25, 1999) show fewer sagebrush seedlings at higher grass seeding rates, although not statistically significant. Sagebrush seedling density differed among sagebrush seeding rates. On all four sampling dates, sagebrush seedling density was greater for the 4 kg/ha sagebrush seeding rate than the 2 and 1 kg/ha rates. Mean seedling counts on June 30 differed among all three sagebrush rates whereas on August 3, 31, and October 25 the 2 and 1 kg/ha rates had similar seedling densities. Sagebrush seedling density and grass and forb production determined in 2000 will provide us with further information about treatment effects on sagebrush seedling establishment and survival. We anticipate that this study and other recent research on the effects of other cultural practices on sagebrush establishment will enable proposal of a seeding strategy for Wyoming big sagebrush.

Introduction

In arid and semiarid rangelands, where mining has occurred, re-establishment of key vegetative species is critical to maintain function, structure, diversity, and stability of the landscape. Key shrub species have evolved to exploit the limited resources of these regions, and are a vital component of rangeland function. Shrubs provide many benefits to humans and animals including erosion control, industrial products, ornamentals, medicine, functionality of rangeland ecosystems, and wildlife browse and cover (McKell 1989). Precipitation and available soil moisture dictate the distribution of xeriphytic shrub communities across North America (McKell 1989), and their drought tolerance make them well suited to dominate arid and semiarid regions. As a result, shrub communities are

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found in saline valleys, dry deserts, broad valleys, and on xeric slopes. Shrub restoration is an important science across the western United States because of recent attention and heightened ecological awareness paid to surface mine reclamation.

Efforts to re-establish shrubs on coal mined lands was heightened upon adoption of a specific shrub density standard, 1 shrub/m^2 on 20% of reclaimed lands, by the Wyoming Department of Environmental Quality (Wyoming DEQ 1996). Attaining shrub density standards for Wyoming big sagebrush (*Artemisia tridentata ssp. wyomingensis*) in the Powder River Basin of Wyoming have proven difficult. Problems encountered with sagebrush re-establishment include low seedling vigor, slow growth habits, poor seed viability, disease, injury or excessive browse from livestock and wildlife, and competition from herbaceous species (Harniss and McDonough 1976, DePuit 1988, Young and Evans 1989, Schuman et al. 1998).

Past studies have shown that sagebrush seedling establishment is dependent upon moisture availability (Jones 1991), arbuscular mycorrhizal infection (Allen 1984, Stahl et al. 1998), and herbaceous competition (Schuman et al. 1998). There are a number of approaches to resolve competition and water stress on shrub seedlings. For example, straw and stubble mulches can be used to enhance soil water retention, reduce diurnal temperatures, increase microbial activity, and to enhance "safe-site" development for seed/seedlings (Schuman et al. 1980, 1998). Practices such as mowing, interseeding, and two-phase seeding can alleviate competitive pressures on shrub seedlings (DePuit 1988). The rate and time of seeding can also influence shrub seedling survival. Although rate of seeding can be manipulated to reduce environmental and competitive stresses, successful guidelines have not been established for mined lands. Successful reclamation techniques require proper and effective seeding rates to accelerate and direct plant succession toward desired conditions.

This study examines sagebrush seeding rate and herbaceous competition treatment effects on Wyoming big sagebrush establishment. Guidelines for proper seeding rates of native shrubs, especially Wyoming big sagebrush, are vital management strategies for mined lands of the Powder River Basin.

The objectives of this study are to investigate three factors affecting sagebrush seedling establishment on mined lands: 1) influence of grass competition on Wyoming big sagebrush germination, emergence and establishment 2) effects of sagebrush seeding rates on sagebrush seedling density and survival, and 3) the interaction of sagebrush seeding rate and grass competition on sagebrush seedling establishment and survival.

Materials and Methods

The study area is located at Belle Ayr Coal Mine, RAG Coal West, Inc. 29 km southeast of Gillette, Wyoming. The Powder River Basin is situated between the Black Hills and Big Horn Mountains in northeastern Wyoming. This area has a continental, temperate, semiarid climate. The landscape is characterized by rolling plains and divides with steep escarpments separating plain-like areas from dissected areas with terraces and sloping alluvial fans along streams. Average annual precipitation at the Belle Ayr Mine is 380 mm and average temperature is 7.2°C (L.E.Vicklund, unpublished data, 1998). Snowfall averages 132 cm, most of which falls between October and April. Fifty percent of the precipitation occurs between April and July (Bjugstad 1978).

Pre-mining vegetation of the Powder River Basin is northern mixed-grass prairie, which includes localized concentrations of big sagebrush in a matrix of cool- and warm-season perennial grasses. Black sagebrush (*Artemisia nova*) is common to shallow soils while big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) is commonly found on well-drained uplands. Plains cottonwood (*Populus sargentii*) and willow species (*Salix* sp.) surround larger streams in the Powder River Basin. Greasewood (*Sarcobatus vermiculatus*) and salt-tolerant grasses are limited to broad drainage bottoms and some playas in the area. Local soils either formed from Tertiary and Upper Cretaceous aged shale, sandstone, and limestone or from alluvial terraces and fans. Most soils have a carbonate horizon 40-76 cm deep in the soil profile (Glassey et al. 1955).

Experimental units of the study are located on a 36-ha reclaimed site at Belle Ayr Mine. During December 1997 and January 1998, topsoil from a seven-year-old stockpile was spread at 56 cm in depth over spoil material (70 m deep). In April the study area was seeded to 'Steptoe' barley (*Hordeum vulgare*) at the rate of 17 kg/ha. Barley was mowed late summer and again in early fall to provide a stubble mulch.

Experimental Design

The experimental design was a randomized block design with four replicate blocks (27 x 45.5 m). Grass seeding rate treatments of 0, 2, 4, 6, 8, 10, and 14 kg PLS/ha were randomly applied within each block (6.5 x 27 m) and seeded in early December 1998. Three species of grasses, western wheatgrass (*Pascopyrum smithii*), slender wheatgrass (*Elymus trachycaulus*), and thickspike wheatgrass (*Elymus lanceolatus*) were mixed on an equal seed number basis to form a cool-season perennial grass mixture. This mixture was seeded at the seven rates described earlier to provide a variety of grass competition levels. Grass treatments were seeded using a 1.5 m wide double disk drill and seeded about 1.5 to 2.0 cm deep. Each grass treatment plot was divided into 6.5 by 9 m randomly assigned subplots for sagebrush seeding rate treatments. Sagebrush seed collected near Gillette in the fall 1998 was broadcast seeded at 1, 2, and 4 kg PLS/ha in March 1999 within each subplot.

Sampling Methods

Six 1-m^2 permanent quadrats were established within each sagebrush by grass treatment subplot (6.5 x 9 m) to assess sagebrush seedling densities during two summer seasons, 1999 and 2000. Sagebrush seedlings were counted on June 30, August 3, August 31, and October 25, 1999. In June 1999 grass and forb biomass, collected in 28 - ½ m^2 quadrats, was used to assess production relative to grass seeding rate treatments. Sagebrush density will be determined in June and October of 2000 and cover and production of grasses and forbs will be evaluated in July 2000.

Soil moisture content was determined biweekly at 0-5 cm and 5-15 cm depths from June 17 through August 30. Soil core samples were taken in seven random subplots within two replications. Soil temperature was recorded at 5 cm and 15 cm soil depths at the site. In addition, minimum/maximum air temperature and precipitation were recorded on a weekly basis. Soil temperature, air temperature and precipitation were monitored April through October, 1999, and will be monitored again in 2000. Soil samples taken in seven locations at three depths (0-15 cm, 15-30 cm, and 30-46 cm) will be analyzed for soil pH, electrical conductivity, particle size separation, cation concentration (potassium, calcium, sodium, and magnesium), organic carbon, total nitrogen, and phosphorus concentration.

Data Analysis

Analysis of variance was accomplished using a split-plot, randomized block design to assess sagebrush seedling establishment relative to grass and sagebrush seeding rate treatments on each sampling date and across sampling dates. Grass seeding rates are main plot treatments while sagebrush seeding rates are subplot treatments. Least significant difference (LSD) mean separation was used to indicate differences in sagebrush seedling density among the sagebrush and grass seeding rates. Repeated measures analysis of variance was used to determine differences within sagebrush and grass seeding rate treatments over time. Comparison of October 1999 seedling densities with June 2000 densities will be used to evaluate seedling survival. Grass and forb biomass samples were analyzed to find significance among the seven grass seeding rates. Soil moisture data for six sampling dates were analyzed to determine significance between grass seeding rate and soil water content during the 1999 growing season. Treatment effects and mean separations were evaluated at P# 0.05.

Results

Precipitation in spring and summer 1999 exceeded normal at the study area. April, June, and July precipitation were 7.8, 9.6, and 5.2 cm respectively which was 79, 39, and 54 % above the 67-yr average for Belle Ayr Coal Mine. Total grass and forb biomass collected in 1999 averaged 4084 kg/ha (3228 forb, 193 grass, 663 barley), exhibiting no differences among grass seeding rates. As a result of vigorous forb growth the study area was mowed, with small plot mowers, in late July to aid in assessment of sagebrush seedlings and to mimic management practices used on adjacent reclaimed lands. Mowing was maintained at 10-15 cm in height to prevent sagebrush seedling damage.

Soil moisture content declined from June to late July with further declines in late August (Table 1). At 0-5 cm soil depths, soil moisture content differed among sampling dates, irrespective of grass seeding rates. June 17 and August 13 exhibited higher soil moisture content than all other sampling dates. Soil moisture content at 5-15 cm soil depth differed among grass seeding rates, depending on sampling date. Differences in soil moisture were observed on July 1 and August 13 among the grass seeding rates; however, there were no consistent trends.

Table 1. Soil moisture (%) at 0-5 cm and 5-15 cm depths in seven grass seeding rates during summer 1999 at Belle Ayr Mine.

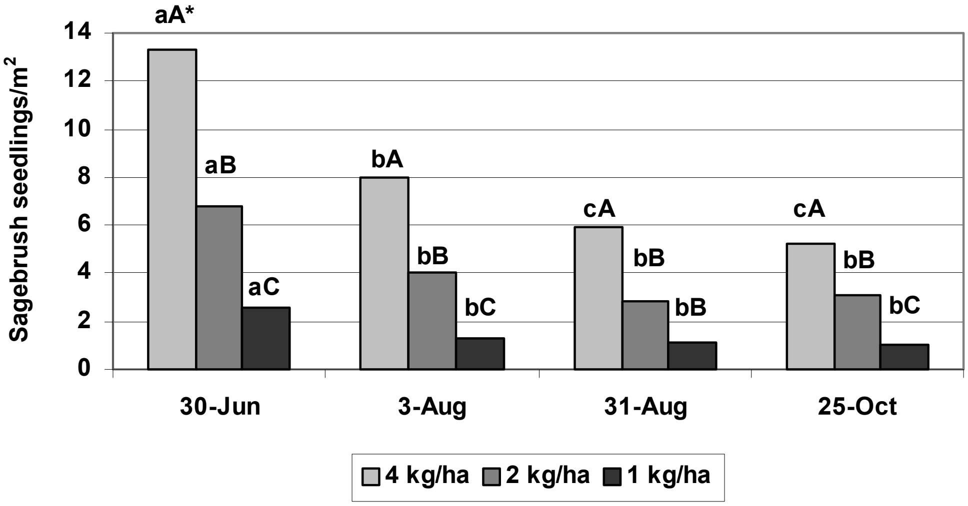
Sampling date	**June 17**		**July 1**		**July 15**		**July 29**		**August 13**		**August 30**	
Soil Depth (cm) Grass rate (kg/ha)	0-5*	5-15**	0-5	5-15	0-5	5-15	0-5	5-15	0-5	5-15	0-5	5-15
0	12.7	15.0 Aa	8.80	9.9 ABbc	6.2	10.5 Ab	5.1	8.9 Abc	18.4	16.9 Aa	4.8	6.6 Ac
2	15.6	18.5 Aa	11.1	12.9 Ab	5.9	8.90 Acd	6.3	9.9 Abc	14.0	11.5 Bbc	5.7	6.2 Ad
4	14.8	16.2 Aa	7.90	8.60 Bb	7.4	8.30 Ab	5.6	9.9 Ab	16.1	15.4 Aa	5.2	7.0 Ab
6	14.6	17.7 Aa	8.70	11.6 ABb	7.1	10.6 Abc	5.8	9.4 Abc	12.1	10.0 Bbc	5.5	7.7 Ac
8	14.6	15.4 Aa	10.9	12.4 Aab	6.2	10.1 Abc	6.9	8.4 Ac	15.1	11.9 Bab	5.7	8.3 Ac
10	14.6	17.7 Aa	9.30	11.3 ABb	7.3	9.50 Abc	4.9	7.3 Ac	17.0	12.1 Bb	5.8	7.2 Ac
14	14.1	16.9 Aa	9.20	12.9 Ab	6.7	8.80 Ac	5.1	8.4 Ac	14.9	10.0 Bbc	6.4	8.7 Ac
Date Mean	14.4 x		9.40 y		6.7 z		5.6 z		15.4 x		5.6 z	

*Within 0-5cm soil depth dates differ; means with the same letter (x, y, z) are not significantly different.

**Within 5-15cm soil depth, grass means within a date with the same uppercase letters do not differ; within grass seeding rate, dates with the same lowercase letters do not differ, $P \geq 0.05$ LSD.

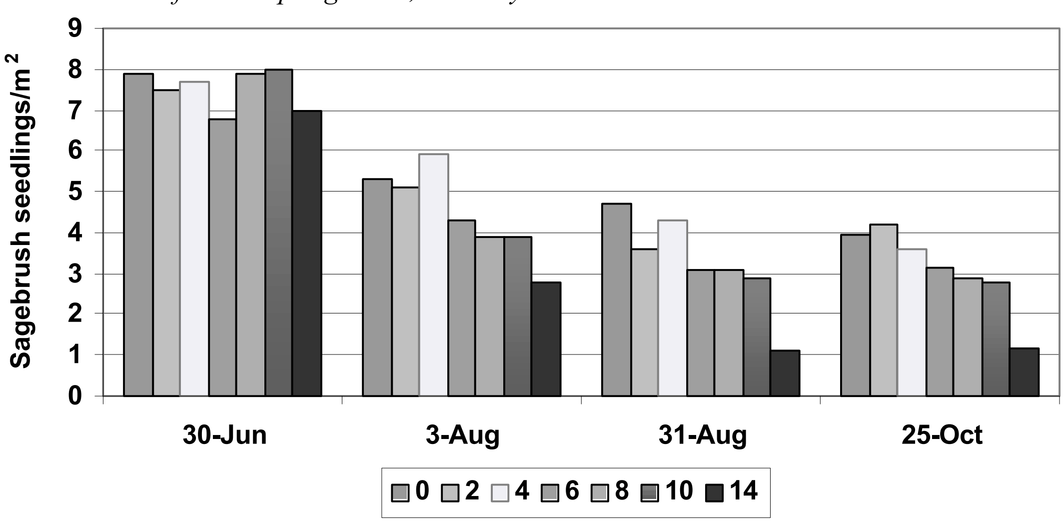
Sagebrush seedling density differed among the three sagebrush seeding rates (Figure 1); seedling density at 4 kg/ha sagebrush seeding rate was greater than the 2 and 1 kg/ha rates on all four sampling dates in 1999. The number of sagebrush seedlings declined during the first growing season in all sagebrush seeding rates. When averaged across sagebrush seeding rates, fewer sagebrush seedlings were observed in the higher grass seeding rates; however, this effect was not statistically significant (Figure 2).

Figure 1. Density of sagebrush seedlings measured from three sagebrush seeding rates on four sampling dates, Belle Ayr Mine in 1999.



*Uppercase letters indicate mean separation among sagebrush rates within a date. Lowercase letters indicate mean separation among dates within a specific rate. Means with the same letter are not statistically different, LSD.

Figure 2. Density of sagebrush seedlings measured from seven grass seeding rates on four sampling dates, Belle Ayr Mine in 1999.



Discussion

Results from the first growing season (1999) suggest limited effects of grass competition on sagebrush establishment. Since precipitation was above normal for spring and early summer months this moisture availability may explain the lack of significant differences in sagebrush seedling densities among grass seeding rates. Soil moisture data at 5-15 cm does show an interaction between grass seeding rate and date, which suggests that grass has a greater influence on soil moisture at deeper soil depths. The 0-5 cm soil samples were more variable in soil moisture over time, as we would expect.

Higher sagebrush seedling density was achieved using 4 kg PLS/ha, although all three rates resulted in sagebrush seedling densities of $\$\ 1/m^2$ in the first growing season. Sagebrush seedling mortality ranged from 49 to 62% with the 1 and 4 kg/ha seeding rates exhibiting the greatest mortality. Mortality of sagebrush seedlings over the growing season could be attributed to lower soil moisture content in late summer.

We anticipate that normal or below normal precipitation and the development of the grass community will cause greater competitive effects of the grass on sagebrush seedling survival in the next growing season. Furthermore, mortality of sagebrush seedlings over the winter may also significantly alter sagebrush seedling density. It appears that with any over-winter mortality the 1 kg/ha sagebrush seeding rate will result in a seedling density $< 1/m^2$ unless further germination and establishment occurs in 2000. Schuman (1999) suggests that higher sagebrush seeding rates, than are normally recommended, be used to ensure the desired density of sagebrush since the seed has been shown to retain viability in the field for several years. He believes this would greatly increase the probability of a good/optimum "precipitation and temperature year" occurring for germination and establishment of big sagebrush without the cost of repeated seeding attempts.

The influence of grass and sagebrush seeding rates on sagebrush seedling establishment will provide us with valuable information about seeding methodology. Our evidence along with recent findings of Schuman et al. (1998) on cultural revegetation methods will furnish reclamationists with guidelines to improve shrub establishment on reclaimed mined lands.

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